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Scott A. Stout, Ph.D.	R&DC-283-99, I

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Battelle 397 Washington St. Duxbury, Massachusetts 02334	U.S. Coast Guard Research and Development Center 1082 Shennecossett Road Groton, CT 06340-6096	11. Contract or Grant No. Grant No. DTRS-57-95-G-00063

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15. Supplementary Notes

The R&D Center's technical point of contact is Mr. Ken Bitting, 860-441-2733, email: kbitting@rdc.uscg.mil.

16. Abstract (MAXIMUM 200 WORDS)

Orimulsion is a fuel that is a bitumen-in-water emulsion made of approximately ~70% natural bitumen and ~30% fresh water. Orimulsion is of great interest to electric power utilities because of its competitive cost and pricing structure. Previous work on Orimulsion has determined it may largely float, remain suspended, or settle depending on the spill conditions. In this study, the mechanisms at work and the relative importance of different spill conditions (e.g., salinity, temperature, energy, Orimulsion concentration, particulate load, and particulate type) are investigated by (1) forty-seven benchtop scale (3L) experiments conducted and evaluated using design of experiment principles and (2) five flume scale (4000L) experiments. The insight gained from these laboratory experiments is interpreted in light of the limitations inherent in laboratory spills into confined vessels (e.g., vessel wall effects and absence of dilution) in order to predict the gross behavior that might be anticipated if Orimulsion were spilled in a 'real world,' open water setting. The most important environmental parameters identified, probably listed in order of their descending importance, were determined to be the receiving water salinity, receiving water energy, and presence/absence of suspended mineral matter. Interactions between these parameters determine whether most bitumen will ultimately float on or near the surface, remain suspended within the water column, or settle through the water column. The gross behavior of Orimulsion under different combinations of these parameters is predicted. These predictions provide the best available guidance to contingency planners and spill responders.

Appendices I through VI are included in Volume II of this report, and are available from the USCG Research and Development Center upon request.

17. Key Words	18. Distribution Statement
Orimulsion, oil spill, bitumen, PAH, petroleum, hydrocarbons, emulsion, design of experiment, flume test	This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161

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EXECUTIVE SUMMARY

Orimulsion, an alternative fuel for power generation, is currently being used in Canada, Italy, Denmark, Japan and China and has been tested in the United States (U.S.) in Florida and Illinois. Orimulsion is being shipped to these locations in ocean-going, double-hull tankers; nevertheless, prudent due diligence requires that the possibility for its accidental release must be evaluated. In order to assess the required countermeasures in case of a spill, a thorough understanding of its behavior when released in water is required. Studies performed to date have demonstrated the importance of the spill conditions on Orimulsion's behavior. For example, these previous studies have shown that receiving water salinity will markedly affect Orimulsion's behavior; i.e., Orimulsion tends to float in salt water. However, the impact and interactions of potentially important independent variables other than salinity are less predictable.

As a result, the need existed to evaluate the behavior of Orimulsion under a wide range and combination of environmental conditions. Better understanding of Orimulsion's behavior under these conditions will provide valuable information useful in developing response actions, assessing mechanical recovery systems' effectiveness, and in developing computer models to predict the fate of Orimulsion following a spill.

This study consists of two principal phases; (1) a benchtop study phase, and (2) a flume tank study phase in which the influence(s) of a number of environmental variables on Orimulsion's behavior were investigated. The benchtop phase utilized design of experiment (DOE) principles in order to reduce the number of experiments necessary to achieve a statistically valid interpretation. Experiments (24) were conducted in which the water salinity, water/air temperature, initial Orimulsion concentration, particulate (mineral matter) loading, particulate type, and water energy were carefully controlled. Other experiments showed the relative unimportance of temperature and particulate type on the gross behavior of Orimulsion. The subsequent response surface design phase (31 additional experiments) provided fundamental information on the mechanisms and processes which different spill conditions have on Orimulsion's behavior. Growth of suspended bitumen particles was most strongly influenced by the combined effects of salinity and energy (bitumen particle coalescence was greatest under brackish salinities (~17.5 $^{o}/_{oo}$) and low or high-energy conditions). The "Orimulsion budget" is the proportion of Orimulsion that floats, settles or remains suspended. A preliminary "Orimulsion budget" (for the bitumen component only) was developed based upon results of the benchtop study.

Caution was necessary in projecting the "Orimulsion budget" from the benchtop to the 'real world.' Benchtop mimicking of 'real world' conditions (e.g., water turbulence profiles, unconfined water volumes, continual dilution of bitumen, the absence of container walls) in a small (4L) laboratory vessel is a challenge. Nonetheless, the benchtop experiments statistical and observational results indicated that (1) water salinity, (2) energy level, and (3) presence/absence of mineral matter in the water were the most important factors in determining the fate of spilled bitumen.

The results of the benchtop experiments were used in developing the second testing phase of the study in which five Orimulsion 'spills' were conducted in a 4000L flume tank. The flume tests

(5) were conducted under a limited set of spill conditions intended to provide data and confirmation surrounding the predicted behavior of spilled Orimulsion. Results of these tests, combined with knowledge from previous flume tank testing of Orimulsion, yielded greater insight into the phenomenon of bitumen particle growth and the "Orimulsion budget."

Flume testing confirmed that the most important environmental parameters in determining the fate of spill Orimulsion, probably listed in order of their descending importance, are:

(1) receiving water salinity,
(2) receiving water energy, and
(3) presence/absence of suspended mineral matter.

The "Orimulsion Budget" was refined and extrapolated to the 'real world' after considering the effects inherent in laboratory tests (e.g., set water volume which precludes dispersion and promotes particle collisions). The predictions of what the bulk of the bitumen component of spilled Orimulsion does under the various combinations of these parameters is presented in the table below. This table is divided into two sections, one in which the salinity is such that the surfactant component in Orimulsion remains mostly effective (top) and one in which the salinity is such that the surfactant component remains mostly ineffective (bottom). The actual salinity which 'divides' these two sections is unknown, but based on our experiments we can only state that the division lies somewhere between 0 and 17.5 $^{o}/_{oo}$.

	WATER ENERGY LEVEL			
	NO	LOW	HIGH	
LOW SALINITY		SUSPENDED - DILUTE (minor settled)	SUSPENDED HIGHLY DILUTE	MINERAL MATTER
	SETTLED TOWARD BOTTOM	SUSPENDED - DILUTE (minor settled)	SUSPENDED HIGHLY DILUTE	NO MINERAL MATTER

	WATER ENERGY LEVEL			
	NO	LOW	HIGH	
HIGH SALINITY		FLOATING - DILUTE (some suspended > some sink)	FLOATING HIGHLY DILUTE (some suspended > some sink)	MINERAL MATTER
	FLOATING NEAR SURFACE (some suspended)	FLOATING - DILUTE (some suspended > some sink)	FLOATING HIGHLY DILUTE	NO MINERAL MATTER

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